Nutritional Composition of Germinated Beans of *Canavalia cathartica*

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Abstract

Cooked germinated beans of ripened pods of mangrove legume *Canavalia cathartica* possess moderate to adequate quantity of proximate composition, essential fatty acids, essential amino acids, protein efficiency ratio, high in vitro protein digestibility and low antinutritional factors. In cooked germinated beans, the crude proteins decreased about 12.7%, copper and zinc marginally decreased, while crude lipid, crude fibre and carbohydrates significantly elevated. Fresh germinated beans were moderate source of several unsaturated fatty acids (e.g. oleic, linoleic and linolenic acids). Oleic acid is known for its hypotensive activity, while linoleic acid favours oxidative-modification of low-density lipoprotein cholesterol, elevates platelet response to aggregation and suppresses the immune system. The albumin fraction elevated significantly in cooked germinated beans and thus retained the sulfur-amino acids as well as essential fatty acids. Some essential amino acids were comparable to soybean, rice and FAO-WHO recommended pattern. There was significant elevation of in vitro protein digestibility in cooked germinated beans along with improved protein digestibility corrected to amino acid score. Cooking germinated beans successfully decreased several antinutritional factors to below threshold level, but retained some nutraceutical components. Thus, cooked germinated beans of mangrove *C. cathartica* serve as future potential beneficial source of nutrition and health.

Keywords

Legume; Canavalia Cathartica; Mangroves; Ripened Beans; Germination, Nutrition

Introduction

Legumes constitute an inexpensive source of proteins with desirable life-supporting traits (e.g. abundance of carbohydrates, lowers the serum cholesterol, high fibre, low fat except for oilseeds, high concentration of polyunsaturated fatty acids and long shelf-life). They are also important source of minerals, B complex vitamins, proteins and energy. India has a convention to grow a variety of grain legumes (e.g. black gram, chickpea, field beans, green gram, lentil and pigeon pea) and their production remained almost static for the past five decades (1951-2000) (10.6-13.7 million tons) due to several factors including climatic/ecological conditions and technological gaps (e.g. non-availability of high-yielding varieties, socio-economic factors and constraints in post-harvest technology) [1].

Among the popular grain legumes, about 30 wild legumes constitute food source of tribal sects in India [2-5]. The wild legumes belonging to the genus *Canavalia* are promising as they grow in wide climatic/ecological niches. Besides nutritional traits, *Canavalia gladiata* consists of a variety of bioactive compounds (nutraceuticals) useful in dietary-management of chronic ailments (e.g. Parkinsonism, diabetes, cardiovascular diseases and cancer) [6]. *Canavalia* is also one of the forage legumes listed under the multilateral system [7]. Recently, some studies have focused on the nutritional properties of *Canavalia* of coastal sand dunes and mangroves of the southwest coast of India [8,9]. *Canavalia cathartica* is one of the major mangrove legumes, which has potential to serve as food source, forage, prevents soil erosion and improves soil qualities. Being a creeper, it covers the mangrove floor and canopy by producing heavy pods during the post-monsoon season. At times, these ripened pods break open in hanging stage and the beans germinate on the canopy (as seen viviparity in some mangrove plant species). The purpose of this study is to document the nutritional components of germinated beans of *C. cathartica* of mangroves of the southwest coast of India in view of its potential to serve as human or livestock nutritional source.

Materials and methods

A. Beans and Processing

Drooping unopened ripened pods of *Canavalia cathartica* Thouars in the canopy (Fig. 1a) were harvested from five sampling sites (0.5 km^2) of Nethravathi mangroves, Mangalore, southwest coast of India (12°50′N, 74°49′E) during post-monsoon season (November-December, 2006). The beans were separated (Fig. 1b), and their weight and dimensions were determined. They were allowed to germinate in five replicates on wet cotton bed until the radical emerge (about 1-2 cm in 5-6 days), and the coat and testa were removed (Fig. 1c). Each set of germinated beans were divided in to two portions, the first portion was sun-dried (4-5 days), while the second was pressure-cooked with freshwater (1:3 v/v) and allowed to sun-dry. Dried fresh and cooked germinated beans were milled (mesh # 30) and the flours were stored in airtight containers in refrigerator for analysis.

B. Proximal Features

The moisture content of the bean flour was estimated gravimetrically by drying at 100°C in an oven until attaining a constant weight. The total nitrogen and crude protein (N×6.25) of the flours were evaluated by micro-Kjeldahl method [10]. Total lipid was extracted in a Soxhlet extractor using petroleum ether [11]. The crude fibre and ash contents were determined gravimetrically based on the methods of AOAC [11]. The Dubois method was employed to determine the total sugars and starch (total sugar × 0.9) [12].

Carbohydrates were calculated based on Müller and Tobin [13]:

Carbohydrates (%) = 100 – (Crude protein + Crude lipid + Crude fibre + Ash)

The gross energy was calculated using the formula by Ekanayake et al. [14]:

Gross energy (kJ/100 g) = (Protein × 16.7) + (lipid × 37.7) + (Carbohydrates × 16.7)

FIG. 1 RIPENED PODS (a), BEANS (b) AND GERMINATED BEANS DEVOID OF SEED COAT AND TESTA (c) OF MANGROVE *CANAVALIA CATHARTICA*

C. Minerals and Fatty Acids

The mineral contents (sodium, potassium, calcium, magnesium, iron, copper, zinc and manganese) of flours were determined by atomic absorption spectrophotometry [11]. Ascorbic acid method was employed to determine the total phosphorus [15]. The fatty acid methyl esters (FAMEs) of total lipids of flours extracted by Soxhlet method were evaluated based on the procedure outlined by Pauda-Resurreccion and Benzon [16]. The analytical conditions of autosampler, injection port settings, column oven settings and column information of the gas chromatograph were followed according to Nareshkumar [17].

D. Protein Fractions, Amino Acids and Protein Digestibility

Total proteins of the bean flours were extracted [18] and estimated [19]. The protein fractions were separated and estimated based on Murray [20] and Lowry et al. [19]. The non-protein nitrogen was extracted, precipitated [21] and estimated by micro-Kjeldhal method [10]. The amino acids of bean flours were assessed by the method outlined by Hofmann et al. [22,23]. The derivatization consisted of esterification with trifluoroacetylation [24].

The essential amino acid (EAA) score was calculated:

EAA score = (mg EAA in 100 mg test protein) ÷ (mg of EAA in 100 mg reference FAO-WHO pattern) × 100

The EAA/Total amino acid (TAA) ratio was calculated:

EAA/TAA ratio (%) = (Total EAA) ÷ (TAA) × 100

The in vitro protein digestibility (IVPD) was estimated according to Akeson and Stahmann [25]:

IVPD (%) = (Protein in digest) ÷ (Protein in defatted flour) × 100

The protein digestibility corrected amino acid score (PDCAAS) of EAA requirement for adults according to FAO-WHO [26] were calculated:

PDCAAS (%) = (EAA in test protein) ÷ (FAO-WHO EAA requirement) × 100

The protein efficiency ratio (PER) was calculated from the amino acid composition of flours based on Alsmeyer et al. [27]:

$PER_1 = -0.684 + 0.456 \times Leu - 0.047 \times Pro$
$PER_2 = -0.468 + 0.454 \times Leu - 0.105 \times Tyr$
$PER_3 = -1.816 + 0.435 \times Met + 0.78 \times Leu + 0.211 \times Hys - 0.944 \times Tyr$

E. Nutraceutical and Antinutritional Features

The total phenolics of the flours were determined according to Rosset et al. [28]. Tannins were estimated by vanillin-HCl method [29]. Canavanine was evaluated using the standard curve by Fearon and Bell [30]. Trypsin inhibition activity of the bean flour was detected by enzymatic assay [31]. The hemagglutinin activity was assessed based on Occenã et al. [32]. The hemagglutination pattern in each well was noted and the hemagglutinating unit per gram (Hu/g) was calculated:
Hu/g = (Da × Db × S) ÷ V
(where Da, Dilution factor of extract in well # 1 was the crude agglutinin extract which remains as 1 if the original extract was not diluted; Db, Dilution factor of well containing 1 Hu was the well in which hemagglutination was first seen; S, ml original extract/g flour; V, Volume of extract in well # 1).

F. Data Analysis

The differences in proximate composition, protein fractions, nutritional features and nutraceutical/antinutritional features between the fresh and cooked germinated bean flours were assessed based on t-test using Statistica version # 8.0 [33].

Results and Discussion

A. Bean Features

The fresh weight of each bean was about 1.7 g consisting about 61% cotyledon and 39% bean coat with L/B ratio 2.89 (Table 1). Even though the weight and dimension of beans of *C. cathartica* was high, unlike the dry seeds the cotyledons contribute only 61% and thus elimination of bean coat resulted in substantial loss of quantity.

TABLE 1 PHYSICAL CHARACTERISTICS OF BEANS OF *CANAVALIA CATHARTICA* OF MANGROVES (N=20; MEAN±SD) (% IN PARENTHESIS)

Fresh weight	
Bean (g/bean)	1.68±0.22 (100)
Cotyledon (g/bean)	1.02±0.14 (60.7))
Coat (g/bean)	0.66±0.12 (39.3)
Dimension	
Length (cm)	2.17±0.11
Width (cm)	1.60±0.21
Thickness (cm)	1.15±0.10
Hilum (cm)	1.59±0.25
L/B ratio	2.89±0.54

B. Proximal Features

Moisture ($p<0.01$), crude protein ($p<0.01$) and starch ($p<0.05$) content of germinated beans significantly decreased on cooking, while crude lipid ($p<0.01$), crude fibre ($p<0.001$) and carbohydrates ($p<0.05$) were significantly elevated in cooked beans (Table 2). But, there were no significant changes in ash and calorific value. Even though the crude protein significantly decreased in cooked germinated beans (24.1 vs. 21%), it surpassed several edible and wild legumes like chickpea (*Cicer arietinum*), green gram (*Phaseolus lunatus* and *P. vulgaris*), pigeon pea (*Cajanus cajan*) and winged bean (*Neonotonia wightii*) [5,34-36] (21 vs. 19.1-20.7%). The crude protein of germinated beans was comparable with ungerminated ripened beans of mangroves (13.8-25.9%) [37] and lower than the ripened beans of coastal sand dunes (30.1-33.4%) [38], while higher than germinated seeds of jack bean (*Canavalia ensiformis*) (24.1 vs. 20%) [39] and Nigerian cowpea (Vigna unguiculata) (24.1 vs. 21.7%) [40].

The crude lipid significantly increased in cooked beans (2.2-2.7%), which is comparable to cooked dry seeds of coastal sand dunes (2.7%) [41] and ripened beans of mangroves (1.52.4%) [37], higher than ripened beans of coastal sand dunes (1.6-1.7%) [38] and lower than

TABLE 2 PROXIMATE COMPOSITION OF GERMINATED BEANS OF *CANAVALIA CATHARTICA* OF MANGROVES ON DRY WEIGHT BASIS (N=5; MEAN±SD)

Component	Fresh	Cooked
Moisture (g/100 g)	9.59±0.83[a]	5.35±0.19[b]**
Crude protein (g/100 g)	24.08± 0.51[a]	21.02± 0.71[b]**
Crude lipid (g/100 g)	2.23±0.16[a]	2.73±0.08[b]**
Crude fibre (g/100 g)	2.21±0.25[a]	2.97±0.13[b]**
Ash (g/100 g)	3.96±0.23[a]	3.40±0.85[a]
Carbohydrates (g/100 g)	67.52±0.59[a]	69.88±1.07[b]*
Calorific value (kJ/100 g)	1614±7[a]	1621±16[a]
Starch (mg/100 g)	65.25±3.71[a]	37.35±3.41[b]*

Figures across the columns with different alphabets between fresh and cooked bean flour are significantly different (*p<0.05; **p<0.01) (t-test)

some edible and wild legumes (e.g. *Atylosia*, *Canavalia*, *Neonotonia*, *Sesbania* and *Vigna*) (2.2-2.7 vs. 4.6-12.3%) [42, 43]. Cooking did not drain the proteins too much in germinated beans in our study (24.1 vs. 21%) unlike fresh cooked ripened beans of mangroves (25.9 vs. 13.8%) [37]. similarly, there was no drastic loss of proteins in cooked ripened beans of coastal sand dunes (33.4 vs. 30.1%) [38]. unlike in ripened beans of mangroves and coastal sand dunes [37, 38], the crude lipid of germinated beans significantly elevated on cooking (2.2 vs. 2.7%). Cooking germinated beans significantly elevated the crude fibre although its concentration was below ripened beans of mangroves and sand dunes (2.2-3 vs. 8.3-10.4%) [37, 38]. The crude fibre of germinated beans was lower than the germinated seeds of four varieties of Nigerian cowpea (2.2 vs. 2.6-3.6%) [40]. the carbohydrate content of the germinated beans was elevated significantly as evident in mangrove and coastal sand dune ripened beans [37, 38]. However, its content was highest in cooked ripened beans of mangrove landrace [37] (69.9 vs. 73.3%). The carbohydrates of germinated beans were higher than germinated Nigerian cowpea varieties (67.5 vs. 63.9-60%) [40]. It is interesting to note that the calorific value did not vary significantly in cooked germinated beans, which corroborates the observations in mangrove and coastal sand dune landraces [37,38].

C. Minerals and Fatty Acids

Except for phosphorus and zinc, the mineral contents of beans decreased on cooking, however it was significant only in calcium (p<0.05), iron (p<0.05) and manganese (p<0.01) (Table 3). The Na/K and Ca/P ratios were ranged between 0.37-0.38 and 1.78-2.48 respectively. Iron and copper in germinated cooked beans and manganese in germinated uncooked beans met the NRC-NAS [44] pattern of requirement for adults. However, the zinc and manganese in mangrove ripened beans and manganese in coastal sand dune ripened beans fulfilled the NRC-NAS [44] requirement for adults [37,38]. Both Na/K (<1) and Ca/P (>1) ratios are in desired proportions (controls blood pressure and calcium loss, respectively) in uncooked as well as cooked germinated beans of mangrove *C. cathartica* [45,46].

Among the FAMEs, lauric, palmitic, myristic, stearic, arachidic and palmitoleic acids in uncooked and cooked germinated beans were comparable or higher than soybean

TABLE 3 MINERAL COMPOSITION OF GERMINATED BEANS OF *CANAVALIA CATHARTICA* OF MANGROVES ON DRY WEIGHT BASIS (MG/100 G) (N=5; MEAN±SD)

Mineral	Fresh	Cooked	Dietary allowance[ψ]
Sodium	55.22±3.19[a]	48.02±12.06[a]	500
Potassium	145.70±8.42[a]	130.94±32.92[a]	2000
Calcium	422.62±24.40[a]	319.71±80.30[b]*	800
Phosphorus	170.32±9.84[a]	179.90±45.04[a]	800
Magnesium	229.40±13.24[a]	204.80±51.44[a]	280-350
Iron	24.91±2.47[a]	13.15±3.30[b]*	10
Copper	2.36±0.14[a]	1.99±0.50[a]	1.5-3
Zinc	3.99±0.23[a]	4.69±1.18[a]	15
Manganese	2.92±0.17[a]	1.30±0.33[b]**	2-5
Na/K ratio	0.38	0.37	0.25
Ca/P ratio	2.48	1.78	1.00

Figures across the columns with different alphabets between fresh and cooked bean flour are significantly different (*p<0.05; **p<0.01) (t-test)

[ψ]NRC-NAS [44]

[47, 48], while the linolenic acid was similar to wheat [49] (Table 4). Compared to the ripened beans of mangrove and coastal sand dune landraces [37,38], the germinated beans of mangroves are superior in fatty acid composition. Oleic acid constitutes an important unsaturated fatty acid in germinated cooked beans, which is known for hypotensive (reducing blood pressure) activity [50]. The oleic acid is also useful as an emulsifying or solubilizing agent in aerosol products [51]. Similarly, the linoleic acid was a major fatty acid in uncooked germinated beans, which favours oxidative-modification of low-density lipoprotein (LDL) cholesterol, increases platelet response to aggregation and suppresses the immune system [52-55].

TABLE 4 FATTY ACID PROFILE OF GERMINATED BEANS OF *CANAVALIA CATHARTICA* OF MANGROVES (MG/G LIPID) (N=5; MEAN±SD)

Fatty acid	Soxhlet method		Soy-bean[£]	Wheat[§]
	Fresh	Cooked		
Saturated fatty acids				
Caprylic acid ($C_{8:0}$)	11.59±0.02[a]	22.22±0.02[b*]	-	-
Capric acid ($C_{10:0}$)	26.31±0.01[a]	33.77±0.02[b*]	-	-
Lauric acid ($C_{12:0}$)	340.90±0.01[a]	402.57±0.02[b*]	Trace-45	-
Myristic acid ($C_{14:0}$)	141.90±0.01[a]	164.91±0.01[b*]	Trace-45	-
Palmitic acid ($C_{16:0}$)	108.51±0.02[a]	99.06±0.02[b*]	110-116	110-320
Stearic acid ($C_{18:0}$)	41.19±0.01[a]	30.71±0.01[b*]	25-41	0-46
Arachidic acid ($C_{20:0}$)	0	2.12±0.01	Trace	-
Lignoceric acid $C_{24:0}$)	0	4.82±0.03	-	-
Polyunsaturated fatty acids				
Palmitoleic acid $C_{16:1}$)	0	4.13±0.02	Trace	-
Heptadecenoic acid($C_{17:1}$)	0	4.03±0.02	-	-
Oleic acid ($C_{18:1}$)	0	96.66±0.03	211-220	110-290
Linoleic acid ($C_{18:2}$)	140.30±0.03[a]	29.04±0.02[b*]	524-540	440-740
Linolenic acid ($C_{18:3}$)	58.40±0.01[a]	12.83±0.02[b*]	71-75	7-44
Eicosadienoic acid($C_{20:2}$)	23.89±0.02	0	-	-
Unknown fatty acids[ψ]	48.01	34.10	-	-
TUFA÷TSFA[¥]	0.33	0.19	3.38-5.97	2.92-5.06

Figures across the columns with different alphabets between fresh and cooked bean flour are significantly different (*p<0.001) (*t*-test)
[£]Wahnon *et al*. [47]; Cho [48]
[§]Pomeramz [49]
[ψ]Fatty acids were not recognized by the standard cocktail of methyl esters (C_4-C_{24})
[¥]Ratio: TUFA, total unsaturated fatty acids; TSFA, total saturated fatty acids

D. Protein Fractions, Amino Acids and Protein Digestibility

The total proteins of fresh beans also significantly decreased on cooking (p<0.05) (Table 5) as seen in crude protein. Albumins were the major protein fractions in fresh and cooked beans followed by prolamins in fresh and globulins in cooked beans. The albumins of fresh beans drastically increased on cooking (7.4 vs. 9.4%) (p<0.001). The globulins (p<0.001), prolamins (p<0.001) and non-protein nitrogen (p<0.001) were significantly decreased between fresh and cooked beans. Compared to the coastal sand dune and mangrove ripened beans [37,38], the germinated beans are poor in true proteins. Unlike highest globulin in mangrove and coastal sand dune landraces [37, 38], the germinated beans of mangroves possess the higher albumin content. Increased albumin in cooked germinated beans reflected in significant elevation of sulfur amino acids as albumin consists of those amino acids. There seems to be difference in albumin fraction than the other protein fractions between ripened and germinated beans of *Canavalia* and warrants further studies.

TABLE 5 PROTEIN FRACTIONS AND NON-PROTEIN NITROGEN OF GERMINATED BEANS OF *CANAVALIA CATHARTICA* OF MANGROVES ON DRY WEIGHT BASIS (G/100 G) (N=5; MEAN±SD) (% IN PARENTHESIS)

Protein fraction	Fresh	Cooked
Total protein	18.96±0.26[a] (100)	17.60±0.41[b*] (100)
Albumins	7.40±0.2[a] (39.03)	9.36±0.21[b**] (53.18)
Globulins	3.94±0.44[a] (20.78)	3.23±0.43[b**] (18.35)
Prolamins	6.35±0.22[a] (33.49)	3.20±0.42[b**] (18.18)
Glutelins	1.27±0.22[a] (6.70)	1.82±0.34[a] (10.34)
Non-protein nitrogen	5.46±0.22[a]	3.87±0.28[b**]

Figures across the columns with different alphabets between fresh and cooked bean flour are significantly different (*p<0.05; **p<0.001) (t-test)

The glutamic acid was highest followed by aspartic acid and leucine in fresh as well as cooked beans (Table 6). Tryptophan was absent in both fresh and cooked beans. The glutamic acid, aspartic acid and histidine decreased significantly between fresh and cooked beans, while rest of the amino acids significantly elevated. The ratio of EAA/TAA was elevated in cooked beans (51 vs. 57%). The amino acid profile of germinated beans are comparable with the mangrove ripened beans [37], while the coastal sand dune ripened beans possess less quantity of amino acids [38]. Except for sulfur-amino acids, the EAA fulfils at least up to 70% requirements stipulated by

the FAO-WHO [26] for adults and also comparable to soybean and rice [56, 57].

The IVPD was significantly elevated in cooked germinated beans (54.1 vs. 78%; p<0.01) (Table 7). It was higher than dry seeds of coastal sand dunes (78 vs. 71.7%) [41] and velvet bean (*Mucuna pruriens*) (78 vs. 49.7%) [58]. Except for tryptophan, the PDCAAS and EAA showed considerable increase in cooked beans. The PER$_1$ and PER$_2$ of fresh beans were elevated up to 1.9 on cooking, while the PER$_3$ has attained up to 0.78 in cooked beans. Due to favorable amino acid composition and IVPD, the PDCAAS of all EAA elevated (with exception of tryptophan) (highest: isoleucine, 87.2%; lowest cystine + methionine, 34.3). The PER$_1$ and PER$_2$ of cooked germinated beans were moderate (1.9), while the PER$_3$ was poor (0.8) [59]. The PER of cooked germinated beans can be improved (>2) by amending the sulfur-amino acids during food formulations [60].

E. Nutraceutical and Antinutritional Features

Among the nutraceutical components, total phenolics (p<0.001), tannins (p<0.01) and canavanine (p<0.01) were significantly decreased in cooked beans (Table 8). Substantial decrease in total phenolics and tannins facilitate to serve as antioxidants than antinutritional components [61, 62]. Consumption of foods rich in phenolic content can reduce the risks of heart disease by lowering the progression of atherosclerosis by acting as antioxidant towards low-density lipoprotein (LDL) [63-65].

The non-protein amino acid, canavanine content in cooked germinated beans was comparable with the seeds of Vicia articulata and V. ervilia (0.11 vs. 0.05-0.3%) and such concentration was considered nutritionally safe or beneficial by Enneking and Wink [66]. Canavanine is an anticancer agent [67], while the lectin (con A) is an antiviral as well as anticancer agent [68, 69]. The fresh and cooked beans were devoid of trypsin inhibitors. The hemagglutinin activity was not seen in fresh beans against blood group A, which was eliminated in blood group O on cooking, while in blood group B it was substantially decreased. Thus, cooking germinated beans decreases antinutritional components in mangrove *C. cathartica*.

TABLE 6 AMINO ACID COMPOSITION OF GERMINATED BEANS OF *CANAVALIA CATHARTICA* OF MANGROVES ON DRY WEIGHT BASIS (G/100 G PROTEIN) (N=5; MEAN±SD) (EAA SCORE IN PARENTHESIS)

Amino acid	Fresh	Cooked	Soy-bean£	Rice§	FAO-WHO pattern¥
Glutamic acid	11.39±0.08^{a}	8.88±0.19^{b**}			
Aspartic acid	8.78±0.06^{a}	8.13±0.17^{b**}			
Serine	3.19±0.02^{a}	4.18±0.09^{b**}			
Threonine	2.62±0.02^{a} (77.1)	3.33±0.07^{b**} (97.9)	3.8	3.2	3.4
Proline	2.42±0.02^{a}	2.86±0.06^{b**}			
Alanine	2.57±0.01^{a}	3.22±0.07^{b**}			
Glycine	2.28±0.0.2^{a}	2.94±0.06^{b**}			
Valine	2.69±0.02^{a} (76.9)	3.56±0.08^{b**} (101.7)	4.6	6.6	3.5
Cystine	0.59±0.01^{a}	0.66±0.01^{b**}	1.7	1.2	2.5$
Methionine	0.32±0.01^{a} (36.4)	0.44±0.01^{b**} (44)	1.2	2.6	
Isoleucine	2.39±0.02^{a} (85.4)	3.13±0.07^{b**} (111.8)	4.6	4.3	2.8
Leucine	4.74±0.03^{a} (71.8)	5.85±0.12^{b**} (78.6)	7.7	8.2	6.6
Tyrosine	2.24±0.02^{a}	2.65±0.06^{b**}	1.2-3.4	3.7	6.3¢
Phenylalanine	2.59±0.02^{a} (76.7)	3.18±0.07^{b**} (85.4)	1.29-4.8	5.1	
Tryptophan	ND	ND	0-1.2	1.3	1.1
Lysine	3.25±0.02^{a} (56)	4.19±0.09^{b**} (72.2)	6.1	3.7	5.8
Histidine	1.68±0.01^{a} (88.4)	1.62±0.03^{b*} (85.3)	2.5	2.4	1.9
Arginine	2.91±0.02^{a}	3.58±0.08^{b**}			
EAA/TAA ratio(%)	50.97	56.95			

Figures across the columns with different alphabets between fresh and cooked bean flour are significantly different (*p<0.05; **p<0.001) (*t*-test)

£Bau*et al*. [57]

§Livsmedelsverk[56]

¥FAO-WHO [26] pattern for adults

$Cystine + Methionine

¢Tyrosine + Phenylalanine

ND, Not detectable

TABLE 7 IN VITRO PROTEIN DIGESTIBILITY (IVPD) (N=5; MEAN±SD) AND PROTEIN DIGESTIBILITY CORRECTED AMINO ACID SCORE (PDCAAS) AND PROTEIN EFFICIENCY RATIO (PER) OF GERMINATED BEANS OF *CANAVALIA CATHARTICA* OF MANGROVES

IVPD, PDCAAS and PER	Fresh	Cooked
IVPD (%)	54.06±4.17^{a}	77.98±8.44^{b*}
PDCAAS (%)£		
Threonine	41.66	76.37
Valine	41.55	79.31
Cystine + Methionine	19.68	34.31
Isoleucine	46.14	87.17
Leucine	38.82	70.18
Tryptophan	0	0

Tyrosine + Phenylalanine	41.45	72.16
Lysine	30.29	56.33
Histidine	47.80	66.49
PER[§]		
PER_1	1.37	1.85
PER_2	1.45	1.91
PER_3	0.26	0.78

Figures across the columns with different alphabets between fresh and cooked bean flour are significantly different (*p<0.01) (t-test)

[£]Calculated according to FAO-WHO [26]

[§]Calculated according to Alsmeyer et al. [27]

TABLE 8 ANTINUTRITIONAL AND NUTRACEUTICAL COMPONENTS OF GERMINATED BEANS OF *CANAVALIA CATHARTICA* ON DRY WEIGHT BASIS (N=5; MEAN±SD) (% IN PARENTHESIS)

Component	Fresh	Cooked
Total phenolics (g/100 g)	3.65 ± 0.1^{a} (100)	$2.36\pm0.02^{b**}$ (64.66)
Tannins (g/100 g)	0.001 ± 0.0002^{a} (100)	$0.0004\pm0.0001^{b*}$ (40)
Canavanine (g/100 g)	0.38 ± 0.001^{a} (100)	$0.11\pm0.003^{b*}$ (28.95)
Trypsin inhibition activity	NP	NP
Hemagglutinin activity (Hu/g)		
A+ve	NA	NA
B+ve	120	20
O+ve	120	NA

Figures across the columns with different alphabets between fresh and cooked bean flour are significantly different (*p<0.01; **p<0.001) (t-test)

NP, Not present

NA, No agglutination

Conclusions

Legume seed germination offers several nutritional advantages such as significant increase in albumins, decrease in total and resistant starches, decrease in nitrogen-free extractives due to induction of amylolytic enzymes, increase in protein digestibility and reduce the canavanine content. The present study demonstrated that the cooked germinated beans of mangrove *Canavalia cathartica* possess moderate to adequate quantity of proximal components, calorific value, essential fatty acids, essential amino acids, protein efficiency ratio, high in vitro protein digestibility, desired nutraceutical components and low or negligible quantity of antinutritional factors. Further, evaluation of vitamins, nutraceuticals (e.g. phytates and saponins and L-DOPA) and amendment of deficient nutrients (e.g. sulfur-amino acids) might facilitate to use the cooked germinated beans of mangrove *C. cathartica* for nutritional and health benefits.

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